REPORT DOCUMENTATION PAGE

Form Approved OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
26 February 2002

3. REPORT TYPE AND DATES COVERED
Symposium Paper 26-27 February 2002

4. TITLE AND SUBTITLE
Payload Modular Submarines For An Uncertain Future

5. FUNDING NUMBERS

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8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center Dahlgren Division
17320 Dahlgren Road
Code N10
Dahlgren VA 22448-5100

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
N/A

11. SUPPLEMENTARY NOTES
Prepared for the Engineering the Total Ship (ETS) 2002 Symposium held in Gaithersburg, Md. at the National Institute of Standards & Technology and sponsored by the Naval Surface Warfare Center & the American Society of Naval Engineers

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Statement A:
Approved for public release: Distribution is unlimited

12b. DISTRIBUTION CODE
A

13. ABSTRACT ***(Maximum 200 Words)***
In the multi-polar world, new and uncertain threats to our Navy and nation arise at a rapid rate. Rapid changes in potential payload technologies will enable new missions. Traditional submarine designs are mission-optimized platforms that are only moderately able to adapt to this changing environment through payload modifications or modifications to the limited non-pressure hull area. Facing an uncertain future, the operational community demands future platforms that are *adaptable* and *flexible*. Payload modularity is a transformational concept that endows the submarine force with adaptability to respond to emerging threats in an uncertain future and to readily incorporate the latest technologies. Flexibility is provided through payload bays on each platform, combined with different types of task specific payload modules that enable CINCs to tailor and scale submarine loadout. Further flexibility is provided through larger payload volume with the option to reconfigure or reload in theater. Analysis to date indicates that payload modularity is achievable and revolutionary. The adaptability provided by payload modularity offers compelling military value. Payload modularity offers the potential to provide CINCs with more capability, more rapidly at significantly lower unit cost. After the initial investment to go payload modular, payload modularity enables increased capability with a stable funding profile, at lower annual cost.

14. SUBJECT TERMS
Payload Modular Submarine; Submarine Design; Optimizing The Ship for the Mission

15. NUMBER OF PAGES
11

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

20020326 231

Payload Modular Submarines For An Uncertain Future

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ABSTRACT

In the multi-polar world, new and uncertain threats to our Navy and nation arise at a rapid rate. Rapid changes in potential payload technologies will enable new missions. Traditional submarine designs are mission-optimized platforms that are only moderately able to adapt to this changing environment through payload modifications or modifications to the limited non-pressure hull area. Facing an uncertain future, the operational community demands future platforms that are *adaptable* and *flexible*. Payload modularity is a transformational concept that endows the submarine force with adaptability to respond to emerging threats in an uncertain future and to readily incorporate the latest technologies. Flexibility is provided through payload bays on each platform, combined with different types of task specific payload modules that enable the Theater Commander-in-Chief (CINC) to tailor and scale submarine loadouts. Further flexibility is provided through larger payload volume with the option to reconfigure or reload in theater. Analysis to date indicates that payload modularity is achievable and revolutionary. The adaptability provided by payload modularity offers compelling military value. Payload modularity offers the potential to provide CINCs with more capability, more rapidly, at significantly lower unit cost. After the initial investment to go payload modular, payload modularity enables increased capability with a stable funding profile, at lower annual cost.

INTRODUCTION

As significant changes to our world occur at an accelerating pace, we must re-evaluate many practices. The world today is predominately a global economy in which events in one region quickly can cause turmoil in distant and unexpected places across the globe (Pearlstein 2001). Technologies are developing at a breathtaking pace that will only increase. Rapid technological change in turn fosters economic changes that in turn cause regional upheaval and political shifts resulting in worldwide instability. The need to adapt quickly and effectively is critical in these times of change, and certainly will continue to be the case in the future.

The submarine force should re-evaluate its options to adapt to this changing world. The submarine force should be designed from top down and bottom-up to ensure that future ships support a new force structure that must be both scalable and responsive to rapid and continuous change.

This paper evaluates a dilemma for ship design in these dynamic conditions. Ship design practices must provide a capability to optimize a platform for the mission or for a payload. The design approach to optimize the ship for its payload is the transformational concept of *payload modularity*.

OPTIMIZING THE SHIP FOR THE MISSION: THE RIGHT APPROACH FOR A CERTAIN FUTURE

Throughout the Cold War years, the threat to our nation was relatively well defined being concentrated in the Soviet Republic and other Eastern-Bloc nations that were fairly stable and predictable. The primary submarine missions included blue-water anti-submarine warfare and nuclear deterrence, and did not rapidly change but rather, evolved over a 30-year period.

Likewise, technology in general did not experience significant rapid changes. Submarine technology development evolved with focus on improved quieting, increased speed, enhanced firepower and deeper operating depths to further our open-water ASW capabilities. The development of the "mechanical" technologies to improve quieting, speed, firepower and depth took years to research and develop, and then additional time to design and build into a new submarine class. These technologies evolved slowly over the years and were mostly developed under

sponsorship of the Department of Defense with little, if any, commercial development.

Funding for new submarine classes was forthright and ample to provide research and development of numerous new technologies that were incorporated into the design and construction of many submarines. During the 1980s up to four submarines were procured on a yearly basis. Original acquisition plans called for 29 *Seawolf* submarines to be built over 30 years.

From *Nautilus* to *Skipjack* to *Thresher* to *Sturgeon* to *Los Angeles* to *Seawolf* and even *Virginia*, the technology and design focus was on enhancing *platform* attributes. Herculean efforts were taken by the *Seawolf* program to take a quantum leap in quieting over the *Los Angeles* Class. A gigantic torpedo room was designed to accommodate up to 42 torpedoes with weapon diameters up to 26 inches, which was slightly larger than the largest Soviet Union heavy weight torpedo at that time (25.6 inches). A more powerful and quieter propulsion plant and propulsor were incorporated to provide the demanded speed with improved stealth. New materials were certified and the ship was designed for deeper depths. However, the interface of the submarine platform with the ocean was still limited to tubes restricted in diameter and without flexibility to accommodate many as-yet unplanned payloads. Essentially, the ship could handle the specific payloads for which it was designed. Unless future payloads fit within the same interface parameters as these specific payloads, they would not be accommodated in the future without significant modifications to the ship.

After the demise of the Soviet Union, public and Congressional support for the *Seawolf* submarine waned. The class was ultimately reduced to three submarines. The New Attack Submarine Program was then started to develop a less costly alternative for the *Seawolf* with less emphasis on speed, depth and firepower, though quieting remained important. Modular construction and littoral mission capabilities were emphasized, but acquisition cost reduction was the major justification for this new submarine that ultimately became the *Virginia* Class.

Until recently, submarines were designed for specific, predefined missions. And rightly so, for the design and construction of the lead submarine of a class takes approximately 12 -14 years to realize, once concept studies begin. Because threat and technology evolved slowly, only relatively minor platform modifications might be needed over a ship's life, thereby naturally allowing cost-effective and timely introductions of new capabilities into the fleet. A ship could reasonably be expected to fulfill the national and Navy mission needs throughout its lifetime because those missions and technology changed only slightly over that period.

Projected build rates for the *Virginia* Class are significantly lower than those of the Cold War years. Future funding for submarine platforms is still uncertain. What is certain, however, is that funding challenges will continue as domestic demands, including homeland defense, compete for resources.

OPTIMIZING THE PAYLOAD FOR THE MISSION: THE RIGHT APPROACH FOR AN UNCERTAIN FUTURE.

With the fall of the Berlin Wall, world order changed from bi-polar to multi-polar. New and uncertain threats, ranging from nation-states to terrorist factions, developed rapidly. These new threats are not well defined, but rather are diverse, dispersed and unpredictable as attested by the September 11, 2001 terrorist attacks on our nation. The platform design challenge is to accommodate mission taskings that are likely to change dramatically not only over time but from deployment to deployment.

Commercial markets today are developing information, signal processing, electronic and miniaturization technologies at breathtaking paces. These tremendous advances must be capitalized on to maintain tactical and strategic advantages over our potential adversaries. The 1997 National Research Council Naval Studies Board recommended that the Navy "exploit the spectrum of payload technologies to provide future submarines with an integrated payload

system that is flexible and modular and can covertly carry, launch and recover a wide range of future weapons, sensors, vehicles and forces," and "develop submarine-launched off-board vehicles, both Unmanned Aerial Vehicles (UAVs) and Unmanned Underwater Vehicles (UUVs), for use across all mission areas. Deliberate growth of this adjunct capability can utilize a two-track approach of cheap, expendable systems and expensive, reusable ones (Naval Science Board 1997)." Further, in 1998, the Defense Science Board recommended in its report, "Submarine of the Future," that the next generation submarine "contain a new, flexible payload interface with the water" (Fields) to enable a broader range of sensors and payloads to employ in the future. Looking ahead 30 years, CNO Strategic Studies Group XIX envisioned a myriad of distributed off-board sensors and payloads dispersed in the ocean environment as a forward deployed naval force. They saw the force as agile, scalable, and fully capable of leading or participating in joint or combined operations (Chief of Naval Operations Strategic Studies Group XIX 2000). The platform design challenge is to accommodate capability requirements that are likely to change dramatically over the platform's service life.

The answer to the challenge of capability change over platform life is *adaptability*. The uncertain and ever-changing future environment demands timely *adaptability* to address emerging missions and to readily incorporate the latest technologies. The answer to the challenge of changing tasks from deployment to deployment is *flexibility*. *Flexibility* to tailor and scale the force to the mission tasking will enhance effectiveness by placing the right type and amount of payload where and when needed. Mission-optimized platforms are only moderately able to adapt to a changing environment through payload modifications (e.g., encapsulated cruise missiles) or modifications to the limited non-pressure hull area (e.g., incorporation of vertical launch systems (VLS)). Therefore, a means of rapidly and affordably deploying the latest technologies to counter all threats must be devised. To achieve this adaptability and flexibility, and remain affordable, future submarines must have payloads optimized for the mission through <u>payload modularity</u>.

PAYLOAD MODULARITY

Today, submarine payloads are constrained because they exit the platform through restricted interfaces to the ocean, generally tubes (e.g., torpedo tube, vertical launch system tube (VLS)) that limit payload diameter and type. Many of these payloads are stored within the submarine pressure hull.

In its space programs, NASA achieves such adaptability and flexibility through modularity. The NASA Space Shuttle System is modular with mission-specific, custom-tailored payload modules configured to meet standard interface requirements. Though its missions have varied greatly over many years, the space shuttle orbiters have remained relevant. Shuttle missions have varied from the Measurement of Air Pollution from Satellites (MAPS) experiment (Kennedy Space Center Shuttle Mission Archive STS-2) to Spacelab-1 (Kennedy Space Center Shuttle Mission Archive STS-9) to the launch of the Magellan/Venus radar mapper spacecraft (Kennedy Space Center Shuttle Mission Archive STS-30) to the Hubble Space Telescope (Kennedy Space Center Shuttle Mission Archive STS-31) to construction of the International Space Station (NASA Human Space Flight STS-88 Post-Mission Summary) and myriad internal low gravity experiments (Kennedy Space Center Shuttle Mission Archive NASA Space Shuttle Launches). By designing the space shuttle *system* up-front for a range of future payloads and imposing a minimal set of rigidly enforced interface requirements, the system has been able to adapt to numerous disparate missions.

Also, the International Space Station is constructed using modules with standard interfaces. This allows different nations to construct modules that meet their needs and are compatible with the Space Station by adhering to interface requirements. It also allows for modules to be phased in and out as the space station is upgraded (e.g., one module is designed for use during construction of the space station and will eventually be replaced).

The notion of payload modularity is not new to the maritime world. The surface ship community has evolved from Sea Systems Modification and Modernization by Modularity (SEAMOD) in the 1970s and Ship System Engineering Standards (SSES) in the 1980s to the current Danish STANFLEX (Hornhaver 1995) ships and the German MEKO frigates (Blohm and Voss). Similarly, future modular submarines should be considered. This concept is a revolutionary and *transformational* new approach to the submarine force in that:

- Mission or task-specific capabilities (weapons and sensors) will be provided entirely by payload modules scaled and tailored to the mission that are readily installed and similarly detached, and do not penetrate the submarine hull pressure boundary.
- Essential core capabilities (power, maneuverability, stealth, and speed) will be provided by the submarine platform.

Through the concept of payload modularity, ships and payload modules become pieces of the total submarine force that can be strategically located to reflect the needs of the fleet. The type and number of payload modules can be changed as technologies develop or as new threats arise. Also, they can be located in response to specific threats against our nation.

PAYLOAD MODULE CONCEPTS

The payload modular submarine concept is based on a large payload volume outside of the pressure hull. Payload modules provide self-contained, task-specific capability with minimal but standard interfaces with a *payload interface module.* With large payload volumes external to the pressure hull, payloads are not constrained by existing interfaces with the ocean thereby resulting in *flexible ocean interface.* The payload interface module is critical to payload modularity because it is the linkage between the platform and the payload, defining the size, shape and standard interfaces with the payload module. Figure 1 shows a concept for the payload modular submarine, with the amidships payload modules shown in light gray.

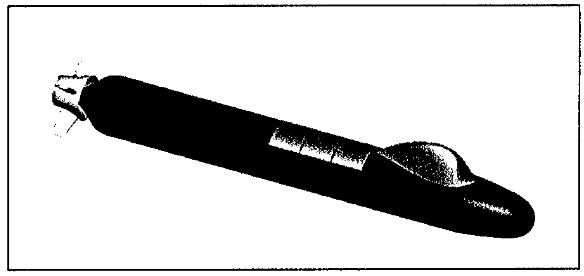

Figure 1: Payload Modular Submarine

Figure 2 highlights the concept of payload modularity, with the payload interface module shown in red and task-specific payload modules dropping into the payload interface module.

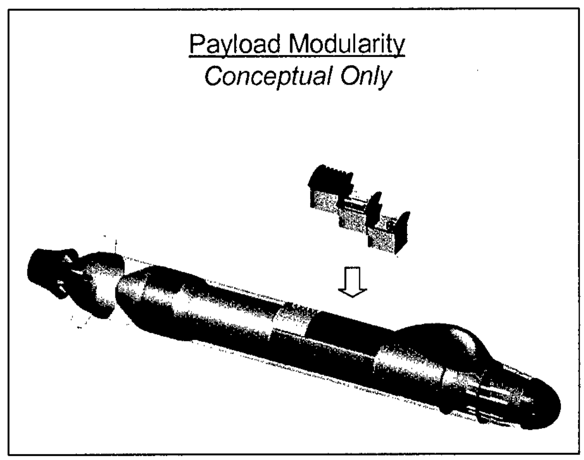

Figure 2: Payload Modularity with Payload Modules

The interface module must provide standard connection interfaces for payload modules including an electrical power bus, a network/control bus (e.g., fiber optic) and standard mating hatches and latches. Payloads would be dropped into the payload interface module. A payload might be launched out the top of the module or dropped from the bottom. The payload interface module is illustrated conceptually in Figure 3.

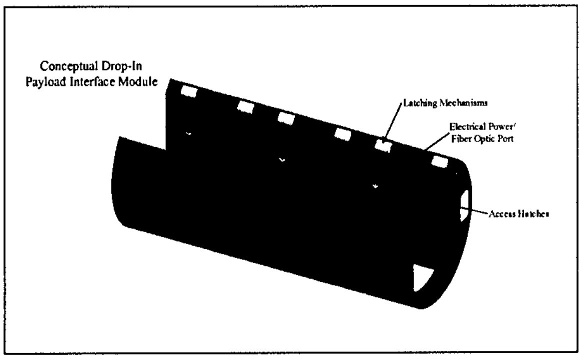

Figure 3: Payload Interface Module – Conceptual Standard Interfaces

Each payload module is custom-designed for the payload (size, watertight or not, pressure proof or not, launch/retrieval mechanism, etc.) and the method of deployment, limited only by size, weight or displacement considerations. Because payload modules are *task-specific,* (e.g., strike) bundles of technological systems with standard interfaces to the platform can be changed out, within three days, to ensure the capability is matched to the assigned task. Figure 4 shows conceptual payload modules. The left payload module is an Intelligence, Surveillance, Reconnaissance, and Targeting (ISRT) Payload Module. It contains small, vertically launched UAVs, two specialized antennas, and two medium sized UUVs. The center payload module is a strike payload module with four sub-modules containing vertically launched missiles as well as required launch equipment. The right payload module is an undersea network payload module, containing undersea network nodes that would be distributed via bottom drop.

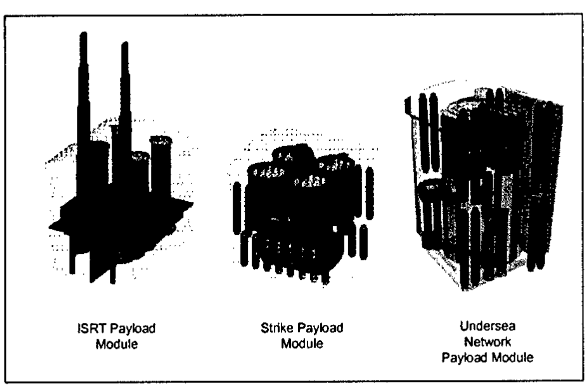

Figure 4 : Conceptual Payload Modules

PAYLOAD MODULARITY PROVIDES ADAPTABILITY

Payload modularity enables the future submarine platform to remain relevant in the joint force by endowing the submarine force with adaptability to respond to emerging threats, at sea and ashore, and to readily incorporate the latest technologies. Because payload modules can be mission-specific and significantly smaller than an entire ship, they require significantly less development, design and construction time and resources than would be necessary to introduce new capabilities into the fleet with a new platform. Payload modules could be developed and field new capabilities faster and cheaper than ever before!

Payload modularity provides the adaptability to readily incorporate the latest technologies. Because payload module development is independent of the platform, new technologies can be incorporated without designing a new platform, redesigning the existing platform or taking the existing platform out of service. Figure 5 depicts a conceptual progression of how a payload module might evolve over time in conjunction with advances in missile and launcher technologies, resulting in significant improved capability.

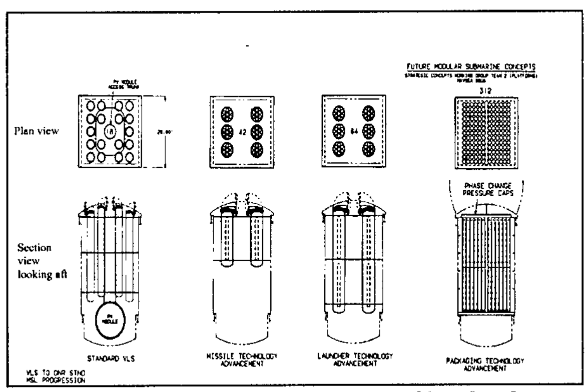

Figure 5: Technological Evolution of Payload Modules

In Figure 5, the left-most drawing is a conceptual payload module incorporating existing VLS technology. Eighteen missiles can be fit in an approximately 20' by 20' payload module with this technology. The second-from-left depiction is a payload module using advanced missile technology with a smaller diameter – the shorter

length "affordable missile" proposed by the Office of Naval Research. Forty-two of these smaller missiles might be fit in the same-size payload module (from a volumetric standpoint). The third payload module reflects potential advancements in launcher technology enabling the ONR "affordable missile" to be double-stacked to have 84 missiles in one module. The right-most drawing reflects advanced technology for missiles to be "dense packed" to yield an upper volumetric payload limit of 312 missiles. These potential missile and launcher technological improvements might be incorporated without designing a new platform or redesigning existing platforms and removing them from service, as long as payload module interface requirements are met.

Payload modularity provides the adaptability to quickly respond to emerging threats by providing new, mission-specific capabilities to be more quickly available to a CINC. The standard interfaces will support the use of the mission-specific modules or sub-modules to all payload modular platforms.

PAYLOAD MODULARITY PROVIDES FLEXIBILITY

Payload modularity enables the Navy to scale and tailor the capability of its force to the task at hand. The payload-modular submarine with its advanced interface provides mission flexibility and greater payload volume when compared to conventional submarine designs. The flexibility from the number and types of payload modules available and the number of payload bays available in a modular submarine force clearly supports many response options. With such a force, capability would be *payload-centric* vice *platform-centric.*

To scale and tailor the ship for the mission, a platform might be configured for "maximum strike" with three strike-payload modules. Alternatively, the platform could participate in the joint environment with a package tailored for amphibious operation support that includes a counter-mine payload module (with unmanned underwater mine reconnaissance vehicles), an ISRT payload module, and a SOF payload module.

Payload modules can be reloaded in theater and payload-modular platforms can be reconfigured in theater, providing the CINC with greater flexibility. For example, covert intervention into terrorist encampments in a distant mountainous region might require large numbers of unmanned aerial vehicles (UAVs) and equally large numbers of precision time-critical strike weapons. A submarine might be outfitted with the requisite payload modules and be on station undetected within days to execute the mission

PAYLOAD MODULAR CONCEPT EVALUATION

NAVSEA Headquarters (SEA 05U), NAVSEA Undersea Warfare Center Division, NAVSEA Surface Warfare Center Division, Systems Planning and Analysis, Inc., RAND Corporation, and Johns Hopkins University/Applied Physics Laboratory conducted a top-down analysis of a potential future submarine force architecture to provide a comparative analysis of a payload-modular approach versus a non-modular approach to submarines. The evaluation was set to the 2025 timeframe and assumed an operating force of 25 payload-modular submarines. The evaluation included both operational effectiveness and affordability of the modular force. A number of conclusions were reached for both effectiveness and affordability.

The adaptability offered by payload modularity has compelling military value. Payload modularity made new capability available to the CINCs more rapidly and across a wider range of platforms than using the conventional non-payload modular approach. The flexibility of the payload-modular force was enabled primarily by increased payload capacity provided as part of flexible ocean interface. If necessary to reload in theater, just-in-time delivery was preferred over prepositioning submodules, based on treaty implications, infrastructure issues, restrictions on handling ordnance, etc. Payloads should be 'packed' in International Organization for Standardization (ISO) sized containers to facilitate

transport and handling. Tailored load outs provide CINCs with additional response options that can help minimize impact of contingencies.

Payload modularity requires a significant up-front investment in Research, Development, Testing, and Engineering and shipbuilder design, including the development of the Payload Interface Module. However, payload modularity's common C^4I interfaces and non-recurring engineering cost reductions would enable the payload modular submarine to achieve cost savings after the initial investment. Since new modular force platforms are not required to put new capabilities or technologies to sea, the payload-modular force has increased capability when compared to the non-modular force, with a stable funding profile, and a lower annual cost. In the long-term, dependent on several factors including construction "learning-curve savings," the costs of a payload-modular force will break even with the non-payload modular force costs. However, the payload modular force will have more capability than a non-payload modular force. Since the whole force can accept payload modules, new capabilities in the form of new modules can be installed in any or all of the platforms vice only those platforms that have been specifically modified, in the case of non-payload modular submarines.

The modular force costs are indeed concentrated up-front. However, the return on investment is greater over time as new capabilities are added. The more changes that occur in the life of the payload modular submarine force, the greater the return on investment for this option. This ability to change capabilities affordably and in less time is of paramount importance in being able to deal with the uncertainties of the future. If one were to conclude that no changes in capability were to ever be needed in the submarine force in the future, then this option is not the one to be pursued.

CONCLUSION

In the multi-polar world order, new and uncertain threats to our Navy and nation arise at a rapid rate. Today's rapid changes in potential payload technologies will enable new missions. Traditional submarine designs are mission-optimized platforms that are only moderately able to adapt to this changing environment through payload modifications (e.g., encapsulated cruise missiles) or modifications to the limited non-pressure hull area (e.g., incorporation of vertical launch systems (VLS)). Facing an uncertain future, the operational community demands future platforms that are *adaptable* and *flexible.*

Payload modularity endows the submarine force with *adaptability* to respond to emerging threats in an uncertain future and to readily incorporate the latest technologies. *Flexibility* is provided through multiple payload bays on each platform that combine with different types of task specific payload modules to enable the CINC to tailor the loadout of the submarine. Further, flexibility is provided through greater payload volume with the option to reconfigure or reload in theater. The adaptability and flexibility provided by payload modularity offers compelling military value. Payload modularity can provide CINCs with more capability, more rapidly and at significantly lower unit cost. After the initial investment to go payload modular, payload modularity enables increased capability with a stable funding profile, at lower annual cost.

Payload modularity is revolutionary but achievable. Payload modularity is a transformational concept that supports a submarine force structure that is scalable, flexible and adaptable to the changes and uncertain threats faced today and into the twenty-first century.

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